AD 714-639

MILITARY MOVEMENTS AND SUPPLY LINES AS COMPARATIVE INTERDICTION TARGETS

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DOCUMENT CONTROL DATA

1. ORIGINATING ACTIVITY	2a. REPORT SECURITY CLASSIFICATION
The Rand Corporation	UNCLASSIFIED
	2b. GROUP

3. REPORT TITLE

MILITARY MOVEMENTS AND SUPPLY LINES AS COMPARATIVE INTERDICTION TARGETS

4. AUTHOR(S) (Last name, first name, initial)

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5. REPORT DATE	6a. TOTAL NO. OF PAGES	6b. NO. OF REFS.
July 1970	34	7

7. CONTRACT OR GRANT NO.	8. ORIGINATOR'S REPORT NO.
F44620-67-C-0045	RM-6308-PR

9a. AVAILABILITY/LIMITATION NOTICES	9b. SPONSORING AGENCY
DDC-1	United States Air Force Project RAND

10. ABSTRACT

An initial attempt to provide a quantitative basis for comparing military unit movements with unit-supply lines as targets for interdiction. Based on U.S. Army unit tables of equipment and standard supply planning factors, the analysis shows that a division movement is considerably more vulnerable to attacks directed against road capacity than that division's supply line would be. Even with all assumptions biased in favor of mobility (no traffic congestion, no vehicle breakdowns, no command control problems, POL available as needed), road movement of an infantry division consumes 6 to 8 times as much of a road's <u>surge</u> capacity as its daily combat resupply consumes of the road's <u>average steady-state capacity</u>. For rail movement, the redeployment/resupply ratio is very large, varying from 127 to 145 times the railroad capacity needed for resupply.

11. KEY WORDS

Interdiction
Logistics
Ground Forces
Tactical Warfare
Air Operations
Tactical Air
Transportation
Deployment

PREFACE

This Memorandum is part of a current study of the strategy and tactics of air interdiction being conducted under Air Force Project Rand. It is directed at the question of worthwhile target systems for interdiction attack. The analysis is short and preliminary, and the intent is to point out the importance of considering military unit movements as profitable interdiction targets.

SUMMARY

In many tactical situations, the movements of military units appear to be more lucrative targets for interdiction than are their supply lines. Significantly more road or railway capacity is needed for a unit move than for its daily resupply requirement; the unit may not accomplish its mission if it is delayed in reaching its planned battlefield location. Furthermore, supplies can be stockpiled over time whereas unit mobility cannot.

A "redeployment/resupply ratio" has been used to make simple quantitative comparisons of the movement of a division's equipment as contrasted with the transportation of supplies for a day's consumption, taking into account the temporary surge increase in road capacity that can be absorbed for a short-duration redeployment but that cannot be sustained over a long period of resupply movements. The assumptions used are biased somewhat toward minimizing the ratio.

Road movement yields a unit redeployment/resupply ratio of about 6:1 on a gravel road and almost 8:1 on a paved road. This ratio was developed using a U.S. infantry division as a base. Road movement of a military unit should consume six to eight times as much of a road's *surge* capacity as that unit's daily resupply consumes of the road's average *steady-state* capacity. A much larger redeployment/resupply ratio, between 127:1 and 145:1, was derived for movements by rail.

When such ratios are considered in relation to the time urgency often associated with the movement of combat forces, countermobility interdiction should be given careful attention in conflicts involving large units of regular military forces; the value of air interdiction should not be assessed on the results of supply line harassment alone.

CONTENTS

I. INTRODUCTION

The word "interdiction" evokes the picture of trucks, trains or oxcarts moving ammunition and other military supplies forward, with air power used against these vehicles and their routes in an attempt to stop or reduce the volume of flow. But as interdiction campaigns of the last thirty years have shown, supply movements are difficult to stop. Further, if strategists and planners equate interdiction with stopping *supply* movements, then decide that the latter job can't be done very well, and cut our interdiction capability, the nation might lose capability that would be very useful against targets far more important than those generally identified with *supply* interdiction.

Recently two Rand analysts have begun to examine *delay* as being itself an objective under certain circumstances, and the movement of *combat forces*, rather than supply networks, supplies and supply vehicles, as the interesting target. It has been argued* that countermobility interdiction should be clearly distinguished from supply-denial interdiction, with different objectives and pay-off functions and partly different target systems. For countermobility interdiction, *surge* movement of combat units rather than *steady-state* movement of supplies would be the focus of attention: time would be of the essence.

This Memorandum is an initial attempt to provide a quantitative basis for comparing unit movements with unit supply lines as targets for interdiction. It is based on U.S. Army unit tables of equipment and standard supply planning factors.

A division is a coherent military organization that may move as a unit, and is also a convenient one for analysis. If the movement distances are at all comparable, many more tons and vehicles are involved in a division movement than in a day's supply for that division. The indication is that a division move is considerably more vulnerable to attacks directed against road capacity than that division's supply line would be. Part of the emphasis on movement over a single road is simply a device for pointing up the problem. The comparisons between unit movement and resupply should still hold if the road net is more dense but interdiction of either would become more difficult.†

It is possible for a division to be supported by or moved over a single road, even in countries with developed road networks. World War II provides examples. Liddell Hart, writing of the German armored advance after the near-collapse of French resistance in 1940, quotes General Blumentritt: "When a place was defended, the bombers were called up to attack it, and then the advanced detachment of the division took it; meanwhile the bulk of the division, without leaving the road, usually waited in a long column (nearly a hundred miles in length) until the road ahead was clear."[1] In the German withdrawal from the Gustav Line during the Italian campaign in World War II, as many as three divisions relied on a single road. In World War I, the many French divisions defending Verdun depended on a single road and a single light railway.

The supply quantity used in the comparisons is the quantity consumed in one day, often called a "day of supply." A day is a logical time period to use for division moves, because a substantial move in a day or two is both possible and militarily significant in many tactical situations. An hour or two is too short for a major unit move; a week or two is longer than many battles last. So the task comparable to a

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*Frederick M. Sallager in a study of interdiction in Italy during World War II, and Edmund Dews in a study of some hypothetical NATO contingencies; these studies are as yet unpublished.

†Analysis of the characteristics of non-division, non-single-road movements is to be the subject of further study.

time-important division move is logically the supply transportation required for a day of combat, not for an hour or a week.

Comparative demands on road space for division movement and for supply transport have been expressed using the "redeployment/resupply ratio," defined and discussed in Section IV.

Several factors that must be considered in an actual deployment have been omitted for this preliminary analysis. Assembly of the redeployment division is assumed to take place rapidly enough so that individual units begin the redeployment as soon as road space is available to them. There is no treatment of traffic congestion at the destination, or of command and control of the move. Vehicle breakdowns are ignored. POL for the redeployment and for the resupply trucks is assumed to be available when and where needed, without any special allocation of road capacity to move it to a point where vehicles are serviced. These and other requirements may involve demands on road capacity, but the nature and degree of these demands will depend on the details of the movement and whether redeployment is forward, lateral, toward or away from depots and supply dumps. They are scenario-specific, and scenarios have not been generated for this preliminary analysis.

II. TRANSPORT REQUIREMENTS
FOR A DIVISION MOVEMENT

DIVISION SIZE

The size of a division varies considerably between national armies, with the U.S. division tending to be larger than others. If we think of the USAF as the interdicting force, then the logical division to describe is one from the Soviet army or from a Warsaw Pact satellite. But for this purpose the force size used is not critical; the aim is to compare the movement of a fairly large ground force to the movement of the supplies this force requires, and secondarily to compare both unit movement and supply movement to the capacity of a road or a railway line.

Because information on U.S. Army divisions is readily available and unclassified, division equipment data and supply consumption rates from FM-101-10-1[2] are used for these comparisons. The relationship between unit size and unit supply consumption should be about the same for any modern, mechanized army in non-nuclear ground warfare. The following comparisons should be reasonably applicable to a ground force which (1) moves by vehicle (not necessarily all organic to the division; but no one has to walk), (2) is about the size of a U.S. infantry division, and (3) has supply requirements typical of those of a U.S. division in the front line in Europe in 1944-1945.

The U.S. infantry division of Chapter 7, Section III of Ref. 2 has about 3700 vehicles, counting tractor/semi-trailer combinations as one vehicle and disregarding other trailers. The breakdown is something like this:

3300 trucks, jeeps, etc.
300 tracked vehicles and self-propelled artillery

100 tractors for tractor/trailer combinations

3700 independently-moving vehicles
2400 towed units, trailers, and semi-trailers

6100 total vehicles

We will assume that all tracked vehicles move on their own, because we wish to deal with a pure case —that in which all elements of the division travel by road. Subsequently we consider another pure case— that in which all elements travel by rail. Note that even if the 300 tracked vehicles came by rail, the total vehicles involved in a division movement by road would be only slightly diminished. If tank transporters were used to save wear on tank treads, the vehicle count would not change.

Reference 2 does provide for some additional trucks; 5 light truck companies, with 45 operable trucks per company, are needed because the division is not quite mobile with its organic equipment.* This adds 225 vehicles. The total has been rounded to 4000 in the following computations. There are 88 helicopters, which should be able to move under their own power.

ROAD REQUIREMENTS

If the division must move forward or laterally over a single road, estimates of the road capacity can be obtained from Army sources, with some help from previous Rand work. The following computations

_____
*See Table 6-2 of Ref. 2.

are based on the "speedometer multiplier" concept, which is explained in detail in Ref. 3, now obsolete. It was also used as the basis for Ref. 4. The current Army motor transport operations manual[5] refers to the speedometer multiplier, but does not explain its use.

The doctrine of Ref. 3 encourages use of a "governed column" movement using the "speedometer multiplier" concept, vehicles maintain a constant time spacing, with each driver keeping behind the preceding vehicle by a constant multiple of speed. The driver may be instructed to stay as many yards behind the preceding vehicle as his speedometer reading in miles per hour, or one vehicle-length for each 10 mph speed. This method is useful for control and avoids an accordion-effect when there is a slowdown at a particular place in the road. The implied 10-yard vehicle length is based on driver perception; the average military vehicle, according to Ref. 3, is about 7 yards long. Ten yards is used as the average for a vehicle with trailer.

The speedometer multiplier will vary by type of movement and type of road. If rapid movement is important, a *normal* formation with a speedometer multiplier of 2 probably will be used on a paved road. More space is required on a dusty road, so a speedometer multiplier of 4 is used for gravel road computations. These are in the *close column* and *open column* range, respectively. Additional spacing must be allowed between units of the division. A factor of 1.87 was used in Ref. 4 and Table 1. This spacing makes no allowance for actual or threatened air attack; countermeasures would probably involve increasing the spacing between vehicles, traveling at night with dimmed lights, and slower speeds. If division and supply movements were equally handicapped, the redeployment/resupply ratio would remain unaffected. Probably the weight of these countermeasures would fall more heavily upon division movement, which would tend to increase the redeployment/resupply ratio.

Division deployment time can be estimated from Table IX of Appendix II to Ref. 3. Tanks average 15 mph and 150 miles per day (mpd); towed artillery, 20 mph and 140 mpd. The 15 mph speed is consistent with Table 2 of Ref. 4 for paved or gravel roads in good or fair condition, some vehicles can move faster, and might do so if their earlier arrival were considered preferable to keeping the unit together on the road. Overall deployment time will be limited by the

slower units. For instance, whether tanks are on transporters or moving under their own power, a 15 mph average may be the fastest we can expect, because any sharp curve will have to be negotiated slowly.

To be precise about the timing of such a move it is necessary to deal in specific assumptions about stops for overnight, meals, and short rest periods. Figure 1 is a projection of the movement of a division over a single road for distances up to 300 miles. Each unit of the division is assumed to be ready to go when its road space is available. Travel time is computed with the following assumptions:

- Average speed while traveling is 15 mph.
- Maximum travel in a 24 hour day is 150 miles.

The first two hours of travel are performed without a rest period. For the next eight hours, enroute halts for food and rest average 15 minutes per hour, so that a 10-hour trip incorporates two hours of enroute halts. The two hours following this are used for travel without halts, so that a 12-hour trip includes two hours of enroute halts and 10 hours of driving. This is followed by a 12-hour rest period and a similar schedule on the following day.

THE EFFECT OF PART-TIME USE

The spacing and division length shown in Table 1 and the movement times given in Fig. 1 imply that the division will make essentially full use of one lane of the road. Cross-traffic is permitted by the interunit spacing factor. But if the road must be shared with other high-priority military traffic, the spread between the first and last elements of the division will be lengthened. If the threat of air attack restricts the movement to hours of darkness, rear elements must make a daytime halt and wait until the next period of darkness to complete the move. The extent of this delay depends on whether units can find concealment almost anywhere along the road, or must be in one of a few specified concealment areas.

Figures 2 and 3 illustrate the effect of these two types of restrictions on the road capacity available to the division. The movement used is the 120-mile deployment for which, as Fig 1 shows, the first elements of the division will arrive at their destination

Table 1

LENGTH OF A DIVISION MOVEMENT

	Paved Road	Gravel Road
Speedometer multiplier used	2	4
Vehicle spacing (gap)* at 15 mph	30 yards	60 yards
Total inter-vehicle spaces for 4000-vehicle movement	120,000 yards = 70 miles	240,000 yards = 140 miles
Total spacing, including spacing between units; 1.87 times total of inter-vehicle spaces	130 miles	260 miles
Total length of individual vehicles†	35,000 yards = 20 miles	35,000 yards = 20 miles
Total length of division movement (road distance)*	150 miles	280 miles
Time to pass a given point at 15 mph‡	10 hours	18 hours 20 min

*These terms are from Fig. 8-1, Ref. 5.
†Vehicles averaging 7 yards, trailers averaging 3 yards
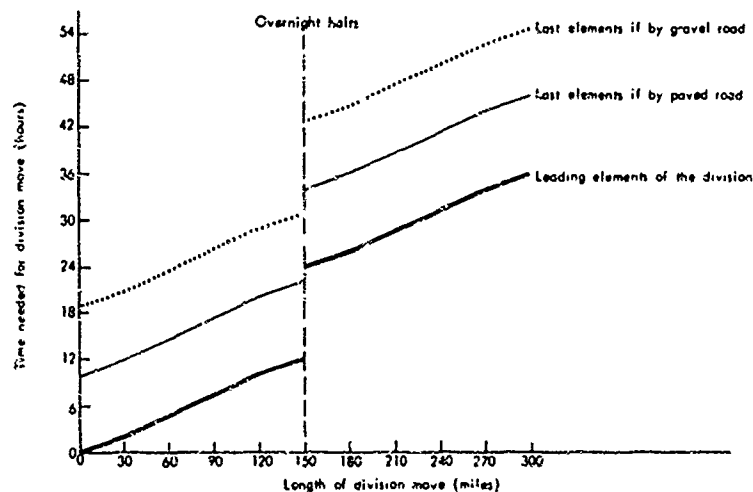‡Not including enroute halts.

Fig. 1—Division deployment time by a single road without air attack or ground opposition
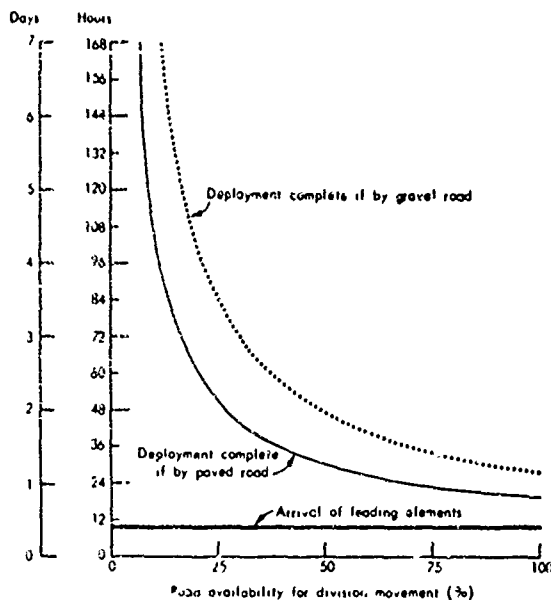
Fig 2—Time for a 120-mile division deployment with part-time use of a single road: availability spread evenly over 24-hour day
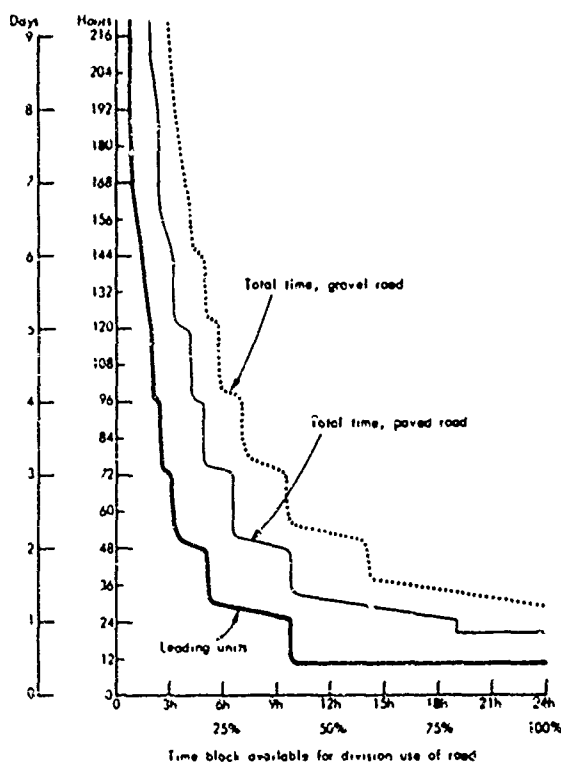

Fig 3—Time for a 120-mile division deployment with part-time use of a single road: division has full use of road for one block of time each 24-hour day

10 hours after leaving their initial point, provided they have full use of the road; the last elements will arrive after 20 hours if the road is paved and after 28 hours 40 minutes if the road is not paved.

The situation illustrated in Fig. 2 is that of a division which has partial use of the road, with the road availability evenly spread during the 24-hour day. Travel time for individual vehicles is not affected, but the number of division vehicles that can use the road in a given hour is reduced to some percent of the normal road capacity indicated by Table 1. This would be the case, for example, if other military movements were required to share the same road at the same time; or if two-way traffic had to be maintained over a one-lane section by using it alternately for outbound and for inbound traffic, or if the load of cross-traffic were heavier than that which could be interspersed between organizational elements of the division.

The situation illustrated in Fig. 3 concerns a division which has full use of a road for a designated block of time out of a 24-hour day, but which cannot use the road for the remainder of the time. This would apply, for example, when roads are unsafe to use in daylight, because of possible attack or a desire for covert movement, or which are not safe to use at night, because of mines or sabotage, or in extremely difficult terrain. For the computations in Fig. 3, it was assumed that units could halt wherever they were at the end of the road-use period, and that they could resume travel from that location at the beginning of the next use period. If it is necessary to look for cover or camouflage vehicles, the time required to do this should be subtracted from the time that otherwise would be available for travel. The leading element of the division starts over the road at the beginning of the time block representing the usable portion of the day; other units follow at the spacing of Table 1 until the end of this time block. Departures resume at the beginning of the time block on the following day.

MOVEMENT BY RAIL

The division may move by train for the major part of the redeployment distance, using its organic mobility only for movement from the initial to the railway loading point, and from the railway unload-

ing point to the destination. Military units were moved over long distances in this manner before the days of full mechanization or motorization.

Railway car requirements for division equipment are not determined by weight, but by vehicle length. The lengths of individual railway flatcars, the number of cars per train, and the resulting train capacity will vary according to railway system and route. To predict how many trains are required to move the division, factors such as gradient, locomotive size, railway practices for assigning more than one locomotive per train, and the lengths of passing sidings on single track must be considered. For the projections given here, it is assumed that a train is 40 cars, and that a car may be a 40-foot flatcar, a boxcar with 30 tons of supplies or non-vehicular equipment, or a freight car carrying 50 troops. We have also assumed that flatcar loading is 90 percent efficient, so that 36 feet of vehicle, on the average, goes on a 40-foot flatcar.

The vehicles of an infantry division total 35,000 yards in length, and will require 2900 flatcars, or 73 trains, to transport them. This assumes that the nonorganic trucks move with the division; if not, the division length is reduced by about 1600 yards, and the railway equipment requirement is for 2800 flatcars, or 70 trains.

Requirements for troop transport will depend on whether any troops can move in their entrained vehicles. If all troops move in separate cars at 50 men per car, the division's 16,000 troops will require an additional 320 cars, or 8 trains. Freight cars are used in this arithmetic because passenger cars are not always available for surge troop movements. One passenger coach loaded to capacity can be substituted for 2 freight cars. Thus, a troop train is approximately 20 passenger cars with 100 men per car.

Troops are assumed to subsist on K-rations or other food not requiring preparation on this sort of a move, and also to forgo the troop sleepers and kitchen cars typical of wartime troop trains in the continental U.S.

Thus the total requirement for division personnel and materiel is calculated to be between 70 and 80 trains. These might be grouped into longer or shorter trains for the actual move, depending on the characteristics of the railway line. If they were given priority over other traffic, they might move over the railway line at a rate of one every hour or two, depending on the frequency of long passing sidings, and thereby tie up a single-track railway for 3 to 7 days. A double-track main line could move the trains in a day or less; so could a single-track line if it were not necessary to return empty trains by the same route during the division movement and if the signal system would permit.

A more significant constraint may come from rolling stock supply or from loading and unloading facilities. Few railway stations can handle several 40-car trains simultaneously. Total division requirement for 2800 to 3200 freight cars may be compared to some national freight car inventories for Eastern Eu   from Ref. 6). This would be a significant slice o   example, Hungary's 19,000 freight cars, particularly as the only usable cars for most of the move are flatcars and removable-side gondolas that can be converted into flatcars. The Czechoslovak inventory of 130,000 could also be tapped, but the Soviet fleet is the wrong gauge.

Both the railway equipment factor and the loading problem may stretch out the movement over several days, permitting individual trains to make several trips and reducing the impact on track capacity.

III. MOVING A DAY OF SUPPLY

REQUIREMENTS

Supply consumption rates vary with the pace of activity in the division area, and Ref. 2 gives an interesting collection of World War II levels in Appendix B. For example:

In Europe, February 24 to March 28, 1945: a day of supply was 42.6 pounds per man per day in the combat zone, and 75 pounds per man per day in the communications zone. (POL and engineer supplies used to move things forward through the COMMZ outweighed, on a pounds-per-man basis, the additional ammunition consumed in combat)

In the European theater during World War II, a day of supply for an armored division in the attack was about 650 tons per day; and that figure was used for this study.

SUPPLIES BY ROAD

Road Capacity

We assume that 163 trips per day by a fleet of 2½-ton trucks loaded to a 4-ton average load could handle the division resupply mission. This would require about 1.1 hours' use of a two-lane paved road, or 2.6 hours' use of a two-lane gravel road, according to the truck flow rates of Ref. 4. These capacities (147 trucks per hour for a paved road and 62 trucks per hour for a gravel road with moderate dust conditions, when the road is wide enough to permit two-way traffic flow) apply to continuous supply operations and are averages, not maxima for a particular peak-load day. If the road could be made available for these military supply convoys for 20 hours per day, with other military traffic, civilian use and maintenance all performed in the remaining 4

hours, a single paved road could carry 11,760 tons per day and a single gravel road 4960 tons, sufficient tonnage to support 18 divisions if the road is paved and 7 divisions if it is not. Other needs and maintenance may take a much larger bite out of capacity; and if the supply trucks have only 12 hours' use of the road per average day, the resulting capacities are 7056 and 2976 tons, still sufficient to support several divisions. Road capacity available for division supply transport is plotted in Fig. 4 as a function of the hours per day of road used allocated to this task. Note that the road capacity available for resupply, in terms of vehicles per hour or per day moving
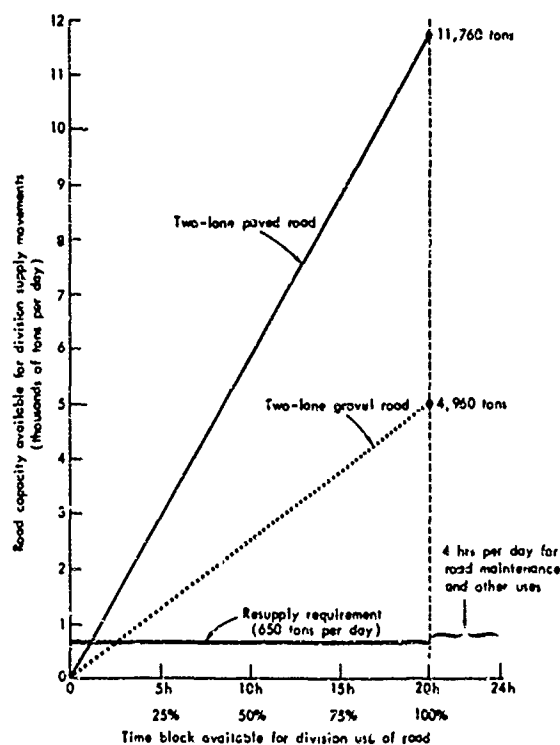

Fig. 4—Hours per day (distributed) and percent of steady-state road capacity available for division supply convoys

8

over the road, is considerably less than the capacity available for division movement. Principal reasons for this are: (1) that moving the division is a surge demand, during which it is possible to postpone civilian traffic, routine maintenance and other activities that reduce total road capacity in the long term; (2) moving a division is also a surge activity for the drivers, who can observe shorter spacings for a single urgent deployment, maintaining a higher level of alertness and breathing more dust, than they would be permitted to do day after day in convoys of supply vehicles.

The road capacities for supply movement cited above allow for added vehicle spacing on gravel roads, because trucks are moving in both directions and must pass through dust clouds raised by vehicles proceeding in the other direction. If supply trucks move over the road with the same spacing as units being deployed, road capacity would be about 400 trucks per hour on a paved road or 220 trucks per hour on a gravel road. At those rates, a paved road would support about 50 divisions and a gravel road about 27 at these active-combat consumption levels.

It does not appear feasible to maintain continuous operations at these surge rates over the entire road system, but short-distance surge-rate operation can be maintained at a few local bottlenecks.

Trucks Needed

The number of vehicles needed for a resupply operation depends on the length of the haul, and on loading, unloading and maintenance time requirements. If the road is available only a few hours per day, as plotted earlier for deployment (Fig. 3), this may increase the number of vehicles required by reducing their utilization. Also, previous assumptions of truck size and loading will not hold for certain road conditions.

Figure 5 shows truck requirements for delivery of 650 tons per day, as a function of distance, for two operating speeds selected from Ref. 4: 23 mph, for a paved road in fair condition in flat to undulating terrain, and 17 mph, for a paved or gravel road in fair to good condition in hilly terrain. A uniform allowance for enroute halts is used; 10 minutes per hour on the road, which is 10 minutes stopped and 50 minutes of driving per hour at the appropriate operating speed. The road is assumed to be available 24 hours per day. Trucks average 18 hours on the
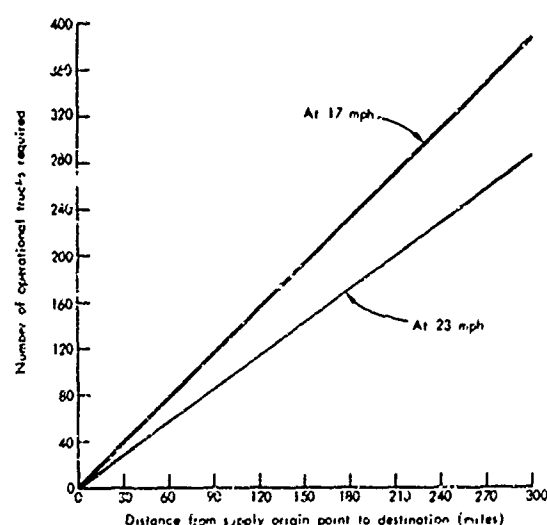

Fig. 5—Truck requirements for a 650-ton daily delivery rate, road available for use at all hours, "non-surge" operation

road with 15 hours of actual driving per 24-hour day. Use of relief drivers obviates the necessity for overnight halts in cases where the haul is too long for personnel to drive straight through with only short rest and meal stops.

The following examples may illustrate the effect of a part-time road closure more easily than can be done with graphs. Truck utilization can be varied by changing the operating schedule for the supply truck convoys, so it is easier to discuss specific illustrations than to generate rules that are effective under many conditions.

The example used is a 120-mile haul over a paved road. Figure 5 shows that 111 operational trucks are needed to maintain the supply flow when the road is open at all hours.

The one-way travel time, including enroute halts, is 6 hours 15 minutes. If the division's day-of-supply is moved in a single convoy, the convoy will include 163 trucks, and the last vehicle of the convoy will start and finish the journey 66 minutes behind the first vehicle. From the first departure until the last arrival, the road time required by the convoy is 7 hours 21 minutes. The following conditions apply to single-convoy operations:

1. If the road is open 16 hours a day, each truck can make one round trip daily, and 163 operational trucks will handle the supply mission.
2. If the road is open 8 hours a day, 325 trucks

will be needed, each making a round trip every two days.

3. For an intermediate-length open period of 12 hours, the truck requirement depends on where the trucks must be when the road is closed. If they are required to be at one end or the other of the supply line, each truck will still require two days per round trip and 325 trucks will be needed. On the other hand, if this 12-hour stop can be made anywhere along the road, if trucks can be serviced wherever the stop is made, and if loading or unloading times can be limited to 15 minutes each, an individual truck can make a round trip in 13 hours of road use, or 1.08 operating periods. Hence, 176 operational trucks can maintain the supply flow.

SUPPLIES BY RAIL

Railway trainloads of supplies are more likely to be limited by weight than by train length. Hence a precise ratio of (the number of trains required to move a division) to (the number of trains required to move a day of supply) will depend on the characteristics of the railway line over which they will move.

For a general estimate, the 30-ton boxcar capacity used for moving division non-vehicular equipment should be close enough. This implies 22 carloads (or 0.55 of a 40-car train) to move the 650-ton daily supply load for the division. If the division does not have direct rail access to its supply point, the division's organic trucks, supplemented by such other vehicles as may be required, must distribute the supplies at destination.

IV. SOME COMPARISONS AND RATIOS

ROAD MOVEMENTS

The two preceding sections indicate a significant disparity between what it takes to *move* a division (or to permit one to move itself) and what is required to *supply* it for a day. If the limiting factor is road capacity rather than the availability of vehicles, a standard ratio for comparison appears useful. The term used for this is "redeployment/resupply ratio," defined as the ratio of two terms:

1. That portion of the road capacity available for redeployment moves which is required for moving a division in a single convoy on a single day.
2. That portion of the steady-state capacity of the road available for supply movements which is required for truck movement of one day-of-supply for the division.

The redeployment of an infantry division described in Section II requires about 42 percent of a day's capacity of a two-lane paved road; movement of a divisional day of supply requires 5.5 percent of the road capacity available for supply movements, if the road is to be kept open to traffic an average of 20 hours a day over the long term. If the road is not paved, the division movement requires 78 percent of a day's capacity, while a day of supply requires 13 percent of the capacity available with 20-hour use.

The redeployment/resupply ratios for this division therefore are 7.6:1 for the paved road and 6:1 for the gravel road.

But these ratios are dependent on a number of assumptions. For example, if larger supply trucks with 8-ton average loads can be used, the supply movement capacity of the road is doubled, and the redeployment/resupply ratios rise to 15:1 for paved roads and 12:1 for gravel.

The redeployment/resupply ratios derived in this

preliminary analysis have been based on a U.S. Army infantry division, for which unclassified data are readily available. But these ratios should generally hold for a spectrum of military units where the number of unit vehicles and unit daily resupply tonnage requirements are of the same order.

Figure 6 provides a nomograph for comparison of the surge and steady-state capabilities for various percentages of road availability.

The comparison is quite sensitive to the underlying logic that much more can be moved over a road in a short-term surge-type unit deployment than in the same number of hours of average steady-state traffic flow. The 9.8 hours of road use by the division, during which 4000 vehicles move over the road, corresponds to a steady-state capacity for moving 1250 vehicles over the same type of paved road.

Now a 50 percent or 75 percent cut in capacity would not substantially reduce the road's ability to support a division with supplies; but the effect of
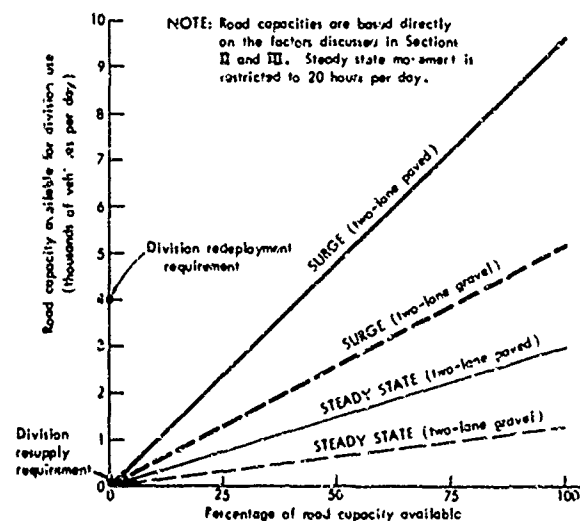
Fig. 6—Vehicles per day versus percent of road capacity

11

such a reduction on division redeployment might have a significant military impact. The key question is the urgency of the division move, because the division can get through eventually if there is some remaining capacity (for example, if it is possible to bypass destroyed bridges), and the division also has some organic engineering capability to repair or get around interdiction points. Table 2 will illustrate this. These reductions in capacity are to be maintained over the period of interest, not just for a few hours or a day. In a redeployment, the period is the length of time rapid troop movements are of military importance; for resupply, the period is generally longer, for example, the duration of the campaign in the location served by the particular road.

RAILWAY MOVEMENTS

Using the assumptions outlined in the preceding sections, the redeployment/resupply ratio for road movement is: 7.6:1 or 6:1, depending on road type.

For railway moves, it is the ratio of 70 or 80 trains for deployment to 0.55 of a train for resupply or, respectively, 127:1 to 145:1.

The most important reason for this difference is that a division which is mobile over the road in its organic vehicles loses this when it moves by train. On the other hand, some sort of transport vehicles must be provided to haul supplies, whether by road or railway. Furthermore, vehicles are loaded less efficiently on railway cars than are ammunition, rations and POL. A third reason for the difference in ratios is that vehicles can operate closer together in a deployment than the average spacing for vehicles in regular supply convoys, and this factor reduces the redeployment/resupply ratio for road moves. The same may be true of railways; but this question has not been treated here because its effect will be on track capacity rather than on the number of trains required.

Clearly this analysis could be refined; but the redeployment/resupply ratio for railways is so large that, even after a change by a factor of 5 or 10, redeployment requirements would dominate those of supply transportation.

Table 2

COMPARATIVE EFFECT OF INTERDICTION ON REDEPLOYMENT
AND RESUPPLY TRAFFIC*

Type of Road	*Fraction of Normal Road Capacity Available*				
	100%	50%	25%	10%	5%
Two-lane paved road:					
(a) Days for division to pass	0.42	0.84	1.67	4.16	8.32
(b) Days to move a division's day of supply	0.06	0.11	0.22	0.55	1.10
Ratio of (a) to (b) = 7.6:1					
Two-lane gravel road:					
(c) Days for division to pass	0.78	1.56	3.04	7.80	15.6
(d) Days to move a division's day of supply	0.13	0.26	0.53	1.30	2.60
Ratio of (c) to (d) = 6:1					

*ASSUMPTIONS: A single road is used for the division redeployment or resupply, and the division has exclusive full-time use of one lane of road, plus occasional use of the other lane, during redeployment. During the resupply period, other traffic and road maintenance requires 4 hours of road use per day. Supply trucks carry 4-ton loads. Capacities for division redeployment are the surge capacities of Section II; capacities for resupply traffic are the steady-state capacities discussed in Section III.

V. IMPLICATIONS FOR INTERDICTION

The redeployment/resupply ratios derived from this preliminary analysis indicate that in many tactical situations military units on the move are potentially a more valuable target for counter-capacity interdiction than regular supply convoys. Interdiction attacks, actual or threatened, may also lead the ground forces to increase the inter-vehicle road interval to avoid presenting concentrated targets for counter-vehicle attacks and, perhaps, to permit units to take cover more rapidly. These countermeasures will add to the time required for the unit to deploy and will waste road capacity.

Another factor to be considered is that while a military unit is likely to move on a schedule based on a time-dependent mission, supplies can be stockpiled in the unit area to cover temporary gaps in supply flow, or to meet peak consumption. It thus seems even more likely that redeployment rather than resupply is the preferred offensive target, and should also be considered the more critical defensive target. This may be true, as Ref. 7 points out, even if the target is far behind enemy lines.

As noted in the introduction, several factors related to interdiction of a unit movement or resupply have not been examined in this preliminary analysis. These factors, such as disruption at the embarkation and debarkation points, use of armed-recce strikes to amplify the traffic congestion and the convoy control problems that would result from the road capacity reduction, and the enroute refuel and resupply problems that would similarly be magnified could prove to be more damaging than reduc-

tion of road capacity by itself. If movement delays, temporary vehicle shortages and major enemy replanning are caused by these harassment attacks, the cumulative effect on the forthcoming ground action may be decisive. A recent study[5] of the effects of the World War II interdiction campaign in Italy in the spring of 1944 (Operation STRANGLE) is of particular interest. One conclusion of this study was that

> The elements of disruption and their synergetic effects must be recognized as indispensable factors in evaluating the effectiveness of an air interdiction campaign.[6]

Southeast Asian insurgencies, with small units that redeploy on foot and merge into the countryside when attacked, are a different case; but in a European context, perhaps the key role for interdiction is in preventing, delaying and disrupting troop redeployment. In this case, a concept of interdiction which depends on harassing the flow of rations, POL, and ammunition to the front may miss the most profitable payoff.

It is probably no coincidence that the number-one success of air interdiction of land transportation to date, the isolation of the Normandy battlefield by destruction of bridges across the Seine and the Loire, was effective mainly against German combat units being redeployed to the front after the German command learned where the invasion was really being mounted.

13

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